Investigating convective gustiness of winds and fluxes using microwave remote sensing

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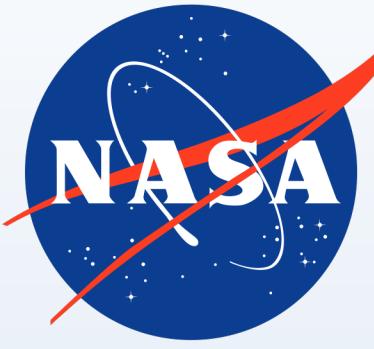
Convective Gustiness

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~100km   ~10-25km
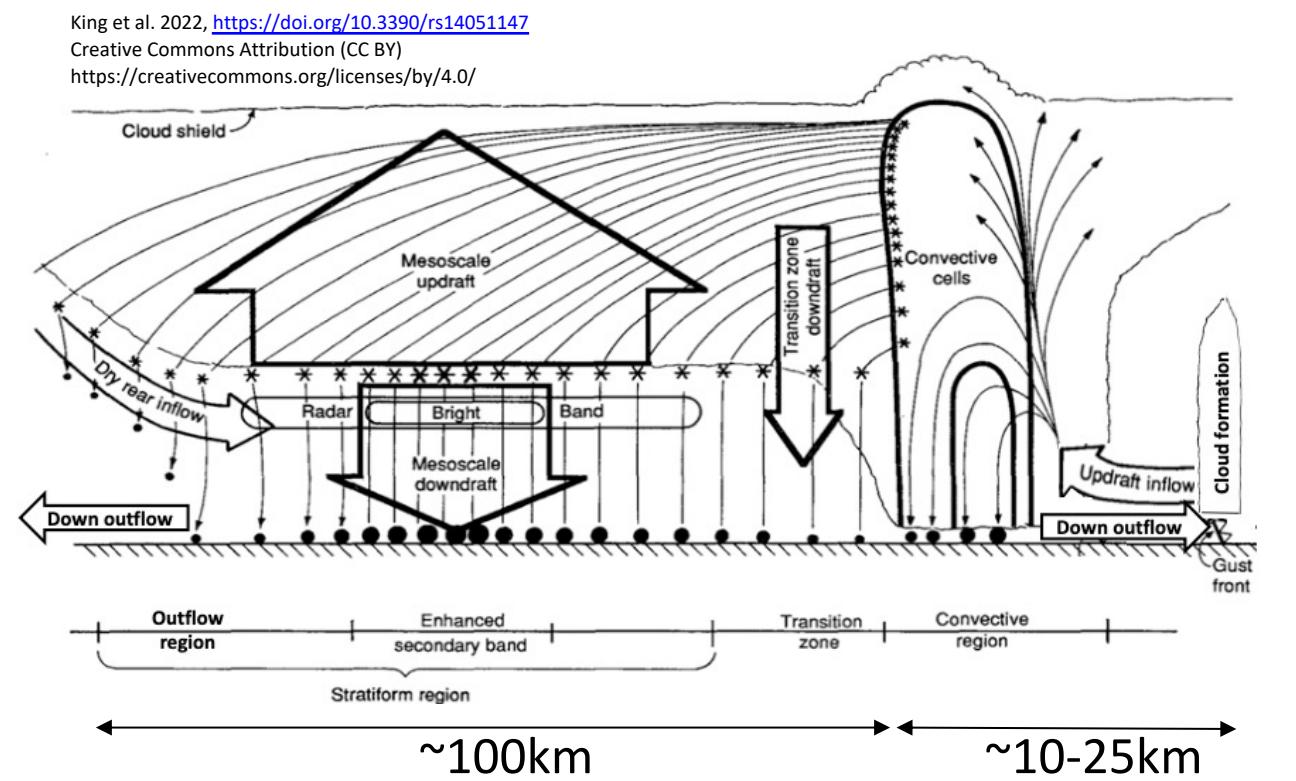
- Variability in ocean winds are driven across multiple scales by different processes:
  - Free convection thermals (~1km)
  - Cold pools and gust fronts (~25km)
  - Mesoscale convective systems (100-150km)

Scalar wind speed: $U = ||\vec{u}|| = \sqrt{(u^2 + v^2)}$

Vector average wind speed: $U_0 = ||\langle\vec{u}\rangle|| = \sqrt{(\langle u\rangle^2 + \langle v\rangle^2)}$

Scalar average wind speed: $\langle U\rangle = \langle||\vec{u}||\rangle \geq ||\langle\vec{u}\rangle|| = U_0$

Wind speed Decomposition: $U^2 = U_0^2 + U_g^2$

- Atmospheric models estimate grid-scale vector average wind speed and a gustiness correction is needed to account for subgrid variability.
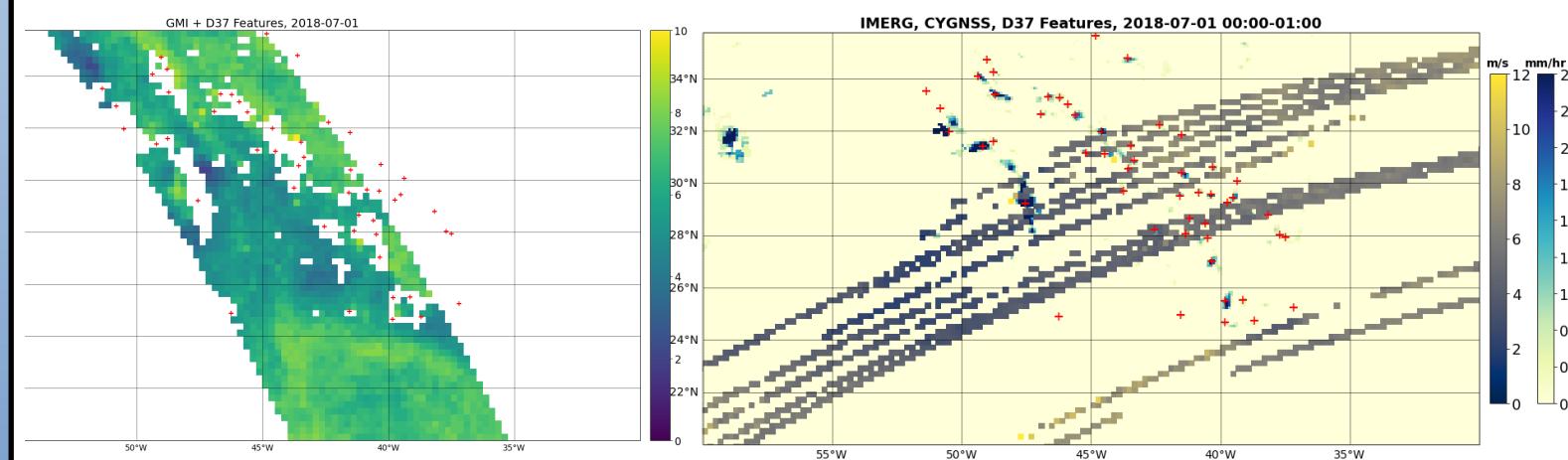
Example of winds from passive microwave radiometer (left) in the presence of rainfall and tracks from CYGNSS observatories (right).

- CYGNSS observations are available in all-weather conditions, and we expect along-track variations in the observed signal to reflect surface roughness driven by wind variability.

Research Motivation and Objectives

- Wind speed variability at scales finer than the resolution of GCMs or general mesoscale wind variability from convective systems enhance the regional surface turbulent fluxes.

- Historical remote sensing observations have systematically undersampled these conditions and atmospheric models rely on parameterizations built upon limited field campaigns and/or coarse-graining of high-resolution modelling.

- Question: *What can we learn about convective wind enhancement across the global tropics using CYGNSS?*

Summary

1. **CYGNSS wind estimates capture mesoscale wind variability and a robust increase in winds and fluxes during atmospheric convection in relation to the surrounding non-raining environment. These estimates generally agree with one-another and with reanalyses.**

2. **The estimated wind/flux signals are generally weaker than found in previous cloud resolving model studies. This is likely due to the inability to provide true-vector wind gustiness contributions which likely dominate. Thus, the enhancements seen here are likely a lower bound on the true increases in wind and wind-related flux enhancement.**

Track-based Analyses

1. Isolate CYGNSS tracks containing convection.

2. Apply QC Filtering and 25km moving average filter

3. Co-register different tracks on a 5km constant sampling track (linear interpolation) and trim to common overlap period so we can isolate and compare features.

4. Identify isolated convective features and determine surrounding 50km environment (non-raining).

5. Compute difference between storm environment wind speed/surface flux and background.

Raw CYGNSS wind speed estimates along a track before (top) and after (bottom) application of processing to QC and isolate events on a common sampling (spatial) grid.
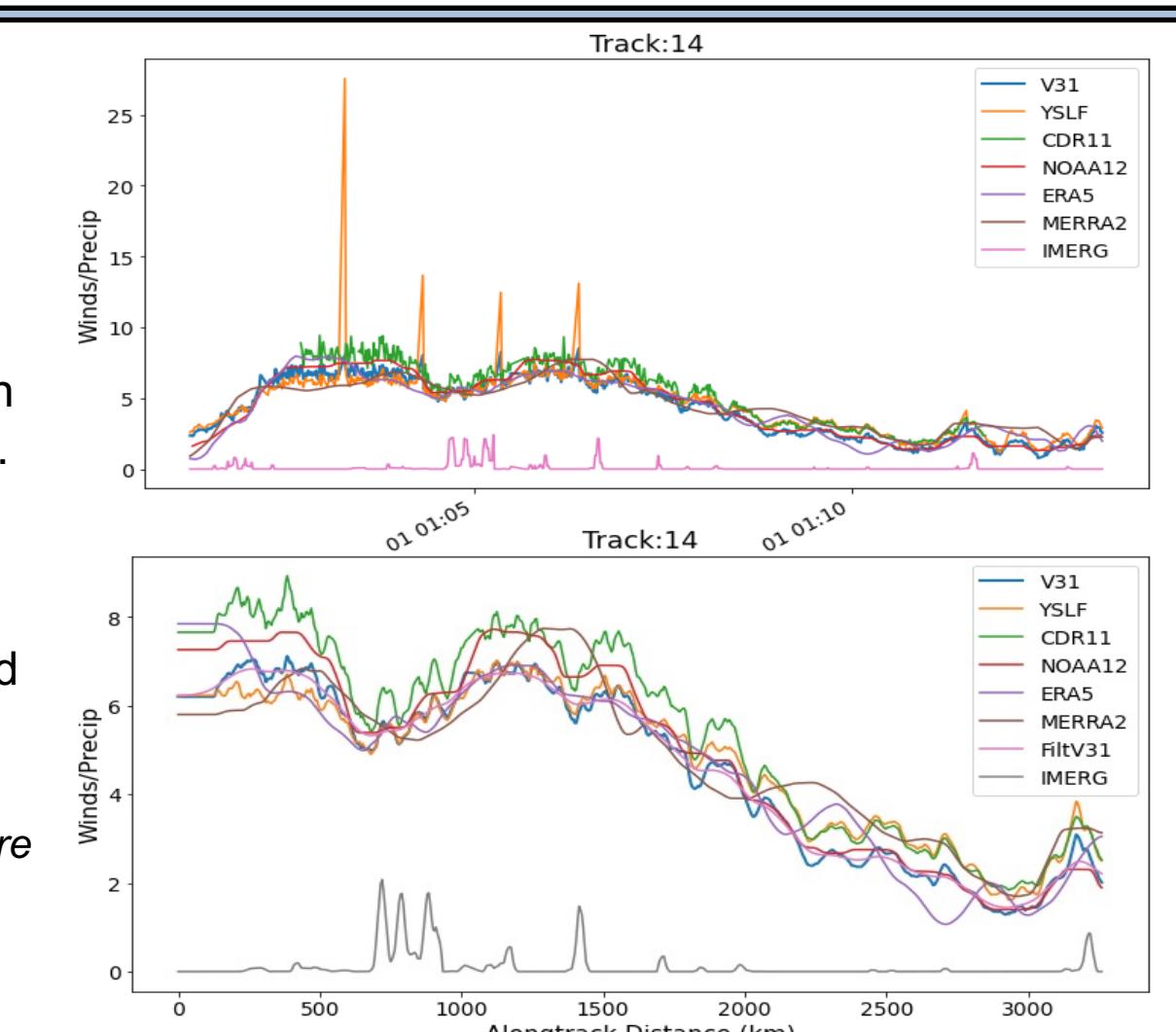
Along-track Variability
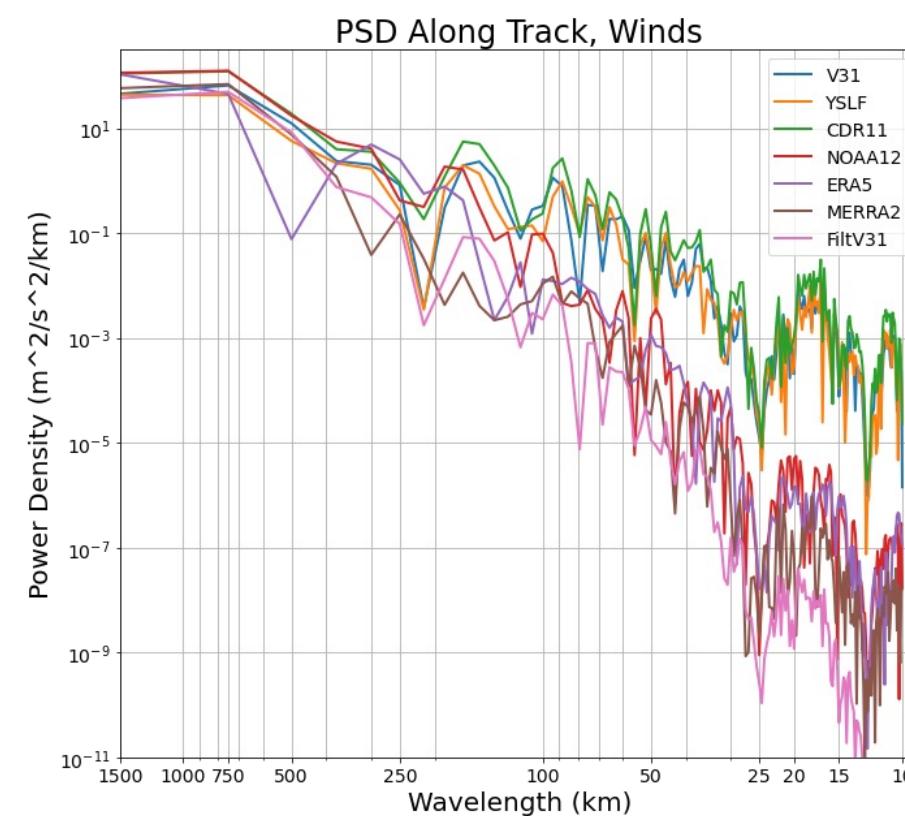
Power spectral density estimates using all tracks longer that 1500km for a single day. Results are illustrated for two reanalyses and four different CYGNSS wind speed estimates.

- CYGNSS V3.1, YSLF, and CDRv1.1 maintain more information at smaller spatial scales (<50km) than NOAAv1.2, ERA5, and MERRA2.
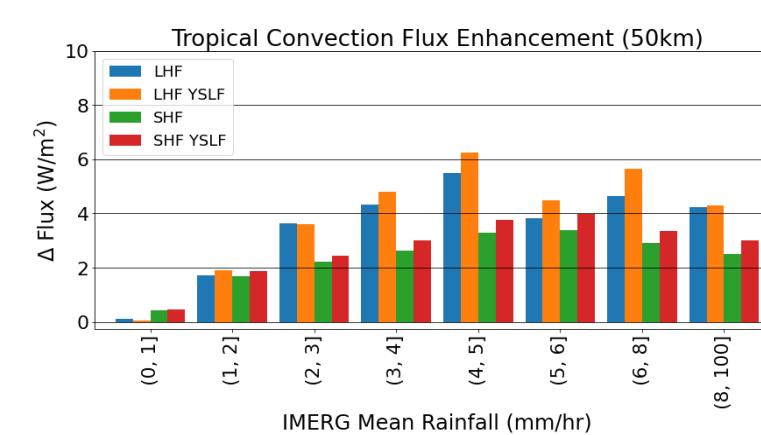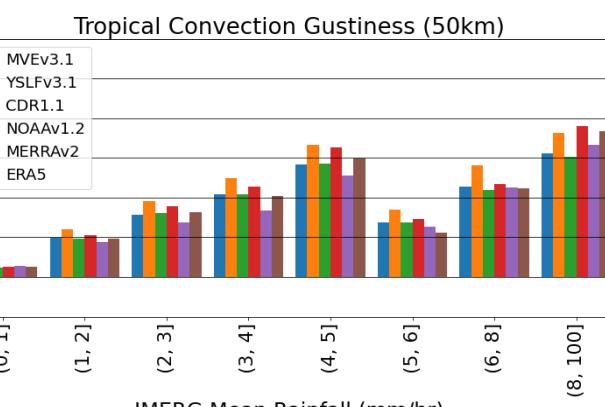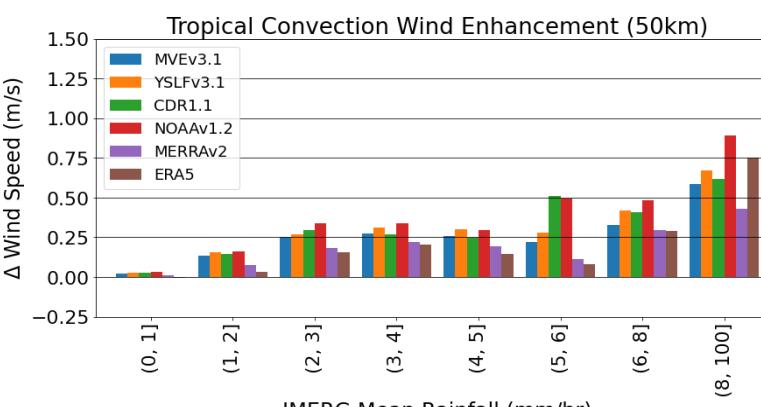
Estimates of convective wind speed and surface flux enhancements relative to the background (left) are shown alongside estimates of convective wind "gustiness" (right) when assigning ERA5 wind directions to CYGNSS scalar winds.

- Scalar wind enhancement is about 0.25 m/s for light to moderate rainfall; increases to 0.5-1.0 m/s for stronger rainfall.

- Wind gustiness is estimated within the storm environment. These are stronger than the scalar wind changes by about 0.5 m/s.

- Clear enhancement of about 5 W/m² in the latent and sensible heat fluxes with increasing mean rainfall.